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Groundwater contamination from uninsulated sewage tanks in an eastern Hungarian settlement

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Abstract: In settlements without sewage systems the uninsulated sewage tanks are the most important sources of groundwater contamination. In our specific eastern Hungarian case study, we attempted to demonstrate the effects of wastewater effluent on the groundwater level and the spatial distribution of the organic matter (OM) and Na^+ in the autumn of 2013. In 2012 we established 3-metre deep monitoring wells within a 25-metre radius of a sewage tank, which were sampled, and the level of groundwater was recorded. The results show that the outflow wastewater formed a groundwater dome. The difference between the groundwater levels measured in the monitoring wells was 49 cm. In the immediate environment of the sewage tank we measured a chemical oxygen demand (COD) of more than 24 mg/l. Moving away from the sewage tank the values decreased rapidly; in the farthest monitoring wells we detected COD values of between 4 and 7 mg/l. The high Na^+ content of domestic wastewaters significantly increases the Na^+ content of the groundwater. In the vicinity of the sewage tank, we detected very high concentrations above 450 mg/l, which continuously decreased when moving away from the sewage tank. In the farthest monitoring wells west and southeast from the sewage tank we measured concentrations of Na^+ of 270 mg/l and 159 mg/l.

Key words: Groundwater salinity, contamination, wastewater, sewage tank, chemical oxygen demand, modelling

1. INTRODUCTION

Domestic wastewater is one of the most important sources of contamination of shallow and deep groundwater supplies, both in the less-developed and the developed areas of the world (Jumma et al. 2012; Jilali et al. 2015; Machiwal and Jha 2015; Smoroń 2016). Salinization and the decrease in the chemical parameters of the groundwater in settlements without sewage system is a common problem (Kang and Jackson 2016; Szabó et al. 2016). As evidenced by several studies, the groundwater salinity is not only governed by mineral weathering and dissolution, but also significantly influenced by anthropogenic inputs (Cary et al. 2013, Chaudhuri and Ale 2014; Yan et al. 2016). Marie and Vengosh (2001) concluded, on the basis of their investigation carried out in the Jordan Valley, that the salinity in the shallow aquifer system could be derived from natural and anthropogenic sources such as the agricultural return-flow and local wastewater of the city of Jericho.

In the rural areas of Hungary, the collection of wastewater remains an unsolved problem in many places (Mester and Szabó 2013; Szabó et al. 2016). Because of the expensive transportation costs, in many cases local inhabitants have chosen to build sewage storage sites in a permeable way, so that the wastewater is able to seep into the soil, resulting in the contamination of groundwater (Mester et al. 2016). In 1990, 43% of households in the public water supply system were not connected to the sewage system, with this rate decreasing to 17.7% in 2014 (KSH 2014). In our case study, we attempt to demonstrate the effects of sewage tanks on the groundwater, carrying out investigations in the immediate environment of a sewage tank. In this study we investigated the amount of organic matter (OM) and the Na^+ content of the groundwater. Since Na^+ has a negligible retardation factor (Sayyed and Bhosle 2011) it is suitable to model the contaminant transport. The aims of this study were the following: 1) to demonstrate the spatial distribution of Na^+ and organic matter (OM) in the immediate environment of the sewage tank, and 2) based on the results, to draw conclusions regarding the level of groundwater contamination caused by the sewage tank.

2. MATERIAL AND METHODS

The settlement is located in the eastern part of the Great Hungarian Plain, in the Nagy-Sárrét region (Fig. 1), and has a population of 2631 (KSH 2015). The Nagy-Sárrét region is an alluvial plain, with a moderately warm and dry climate (Dövényi 2010). Due to the low altitude (85-89 m) compared to neighboring regions the groundwater level can be found close to the surface, at a depth of 1-2 metres. In the sample area the most frequent soil types (WRB) were Solonetz, Vertisol, Kastenozem and Chernozem, while in the built-up area Technosol soils modified as a result of anthropogenic effects could also be identified (Novák and Tóth 2016).

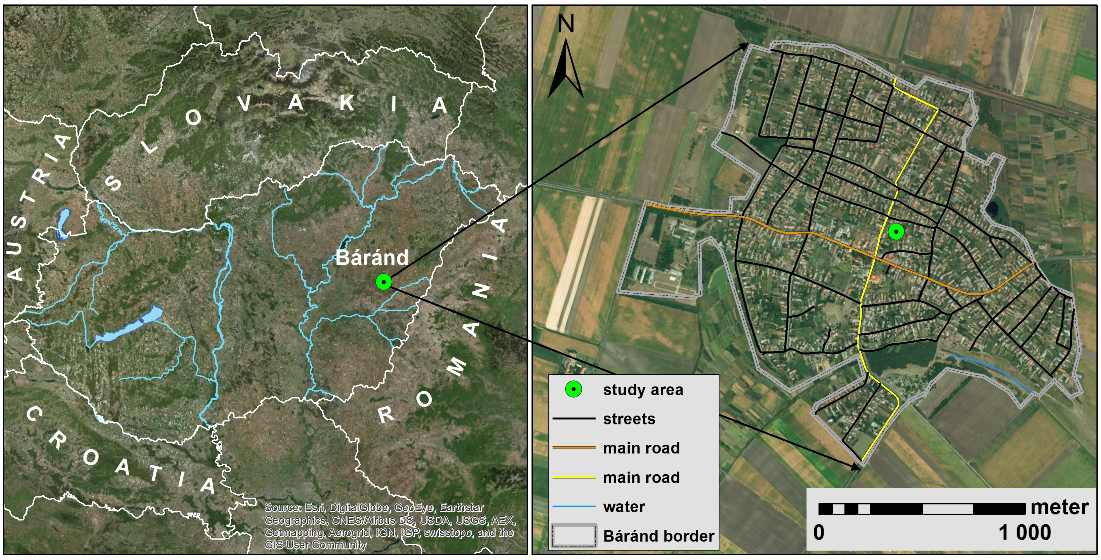

Figure 1. Location of the study area.

In order to analyze the effect on the groundwater of sewage tanks located in the settlement, we selected a sewage tank located in the centre of the settlement (Fig. 1, Fig. 2).

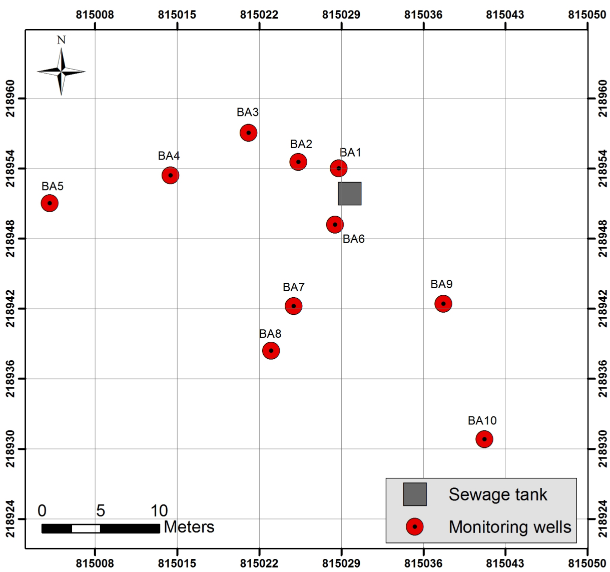

Figure 2. Location of the monitoring wells in the study area.

We established monitoring wells with a depth of 3 metres in the immediate environment of the sewage tank (Fig. 2). The total depth of the monitoring wells was at least one metre deeper than the groundwater level in every case.

The water samples were collected in the autumn of 2013, in accordance with the MSZ 21464 standard. The water chemistry investigations were carried out in the geographical laboratory of the University of Debrecen. The OM content of the groundwater was determined by applying indirect determination methods used for quantitative measurements of the chemical oxygen demand (COD). The Na^+ concentration was measured by using a PerkinElmer 3110 AAS. Soil samples were collected from the BA5 monitoring wells at every 20 cm interval and their granulometric composition was determined by the Köhn-pipette method (Müller et al. 2009).

To identify the exact altitude of the groundwater levels, we used the results of our on-site measurements performed by two Trimble S9 dual-frequency, high precision geodesic GPS systems (accuracy 2 cm). The interpolation of the surface was completed with a free triangular mesh.

The 3D models of the spatial distribution of the OM and Na^+ have been developed with RockWorks 14 modelling software, using kriging interpolation. Based on the solid models created with RockWorks, we have identified the volume of the water bodies contaminated with OM and Na^+ in terms of the given concentrations. Since the soil texture in the investigated area is loam, we calculated on the basis of a pore space of 45%.

3. RESULTS

The values of the COD and Na^+ concentrations and the groundwater levels are summarized in Table 1. The Na^+ concentrations measured in the sewage tank are characteristic of wastewaters (Table 1).

Table 1. Groundwater level, Na+ and COD concentrations in the monitoring wells

Wells	Sewage tank	BA1	BA2	BA3	BA4	BA5	BA6	BA7	BA8	BA9	BA10
mBf	88.92	88.23	87.94	88.01	88.05	87.99	88.32	87.98	87.92	87.93	87.70
COD (mg/l)	300*	24.25	6.32	5.68	6.55	4.12	27.14	6.22	6.13	5.69	6.44
Na^+ (mg/l)	469.1	452.6	323.8	344.1	277.8	272.3	458.7	417.7	288.9	159.6	163.3

**Value characteristic of wastewaters based on Barótfi I. (2003).*

Based on the 3D model created from the groundwater level (Fig. 3), it can be concluded that the outflow wastewater formed a groundwater dome. The difference between the groundwater levels measured in the monitoring wells was 49 cm (Table 1). Because of the wastewater effluent, the COD values measured in the groundwater exceeded the contamination limit of 3.5 mg/l characteristic of groundwaters (201/2001 Government Decree) (Fig. 3/I).

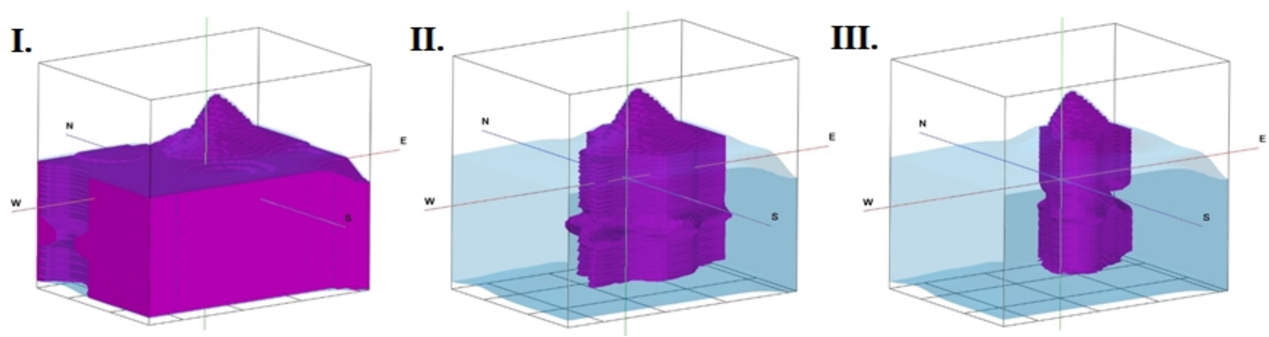

Figure 3. Spatial distribution of COD. I. higher than 3.5 mg/l, II. higher than 10 mg/l, III. higher than 20 mg/l

In the study we modelled the contamination of the groundwater down to a depth of 3 meters from the surface. Based on our calculations, in the case of OM the total water volume of 801 m^3 can be considered contaminated (Table 2, Fig. 3/I). The volume of the more contaminated water body characterized by a value of at least 10 mg/l is 215 m^3 (Fig. 3/II). The volume of the groundwater body characterized by at least 20 mg/l was 101 m^3, which could evidently be measured directly near the sewage tank (Fig. 3/III). By investigating the spatial distribution of COD values it can be concluded that moving away from the sewage tank, the organic material content of the groundwater decreased constantly. This was caused by the dilution of the pollution and the decomposition of OM. Whereas in the BA1 monitoring well located 1 meter from the sewage tank, we detected a concentration of 24.25 mg/l, in the BA5 monitoring well located 25 metres from the sewage tank we detected a concentration of only 4.12 mg/l.

Table 2. The volume of water bodies with different levels of contamination

COD	Volume of water body (m^3)	concentration Na^+	Volume of water body (m^3)
20 mg/l <	101.3	**400 mg/l <**	126.4
10 mg/l <	215.4	**300 mg/l <**	352.9
3.5 mg/l <	801,7	**200 mg/l <**	718.9
total	801.7	**total**	801.7

Based on the spatial distribution of the Na^+ concentration we can also conclude that the effluent wastewater resulted in a groundwater characterized by a concentration which exceeded the contamination limit of 200 mg/l in the majority of the sample area, which affected 90% of the investigated water body (Table 2, Fig. 4/I). A concentration above 300 mg/l was measured in 44% of the investigated water body (Table 2, Fig. 4/II), while a Na^+ concentration above 400 mg/l could be detected only in the vicinity of the sewage tank in a water body with a volume of 126 m^3, which made up only 16% of the investigated water body (Table 2, Fig. 4/III).

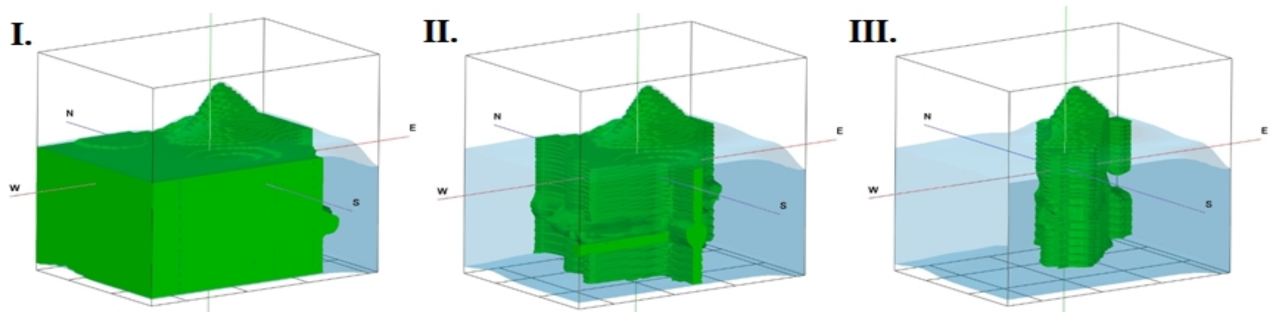

Figure 4. Spatial distribution of Na^+, I. higher than 200 mg/l, II. higher than 300 mg/l, III. higher than 400 mg/l

In the vicinity of the sewage tank, we detected very high concentrations above 450 mg/l, which decreased continuously by dilution as we moved away from the sewage tank. In the farthest monitoring wells west and southeast from the sewage tank we measured 272 mg/l and 159 mg/l.

4. CONCLUSIONS

The results of our investigation clearly show that in settlements without a sewage system, the water effluent from the uninsulated sewage tanks significantly modifies the level and the chemical characteristics of the groundwater. The wastewater effluent from the sewage tank forms a groundwater dome, the height of which was 49 cm at the time of measurement. In the immediate environment of the sewage tank we measured high Na^+ and COD values, which decreased as we moved away from the tank. Using the 3D model we were able to precisely determine the volume of water bodies with different levels of contamination. The Na^+ content of the groundwater exceeded the contamination limit of 200 mg/l in 90% of the sample area. The high salinity of the groundwater is clearly the consequence of the effluent wastewater, evidenced by the fact that the Na^+ concentration rapidly decreased when moving away from the sewage tank, but at the same time, lithological factors can also play a role in the Na^+ concentration since saline soils can also be found in the vicinity of the sample area. The COD values exceeded the contamination limit of 3.5 mg/l at every measurement point; therefore the groundwater can be considered 100% contaminated in the sample area. Therefore, regarding the two water quality parameters investigated (COD, Na^+) it can be concluded that the contaminating effect of an uninsulated sewage tank could be clearly detected within a circle with a radius of 25 metres. However, the extent of the contamination decreased to the level of the contamination limit at a distance of 25 metres from the sewage tank.

Despite the fact that the subject of our investigations was the effect of a specific sewage tank on groundwater, we can assume that similar processes could occur in other households in the settlement, which should be considered during the groundwater quality investigations in the settlement. The experience of this case study could be useful for the investigations of groundwater in settlements with similar characteristics.

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